ENVIROSAT–2000 Report

The U.S. Weather Watch: A Composite System

July 1985

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

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Washington, D.C.
July 1985

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U.S. WEATHER WATCH: A COMPOSITE SYSTEM

ABSTRACT

The observing system is a key element in monitoring local and global weather, and is essential to the provision of forecasts and services to the Nation. It has changed greatly over the past century, and its evolution over the next 15 years is expected to be even more rapid. This paper reviews those expected changes and other key NOAA programs.

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I. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) is the Federal agency charged with monitoring and forecasting the weather for the United States. The warning and forecast system of NOAA has evolved over the years in response to the needs of the Nation and the technological opportunities for meeting those needs. For decades, the U.S. Weather Bureau had little more than limited, manually produced observations of surface weather upon which to base its services.

In the first half of the 1900's, sporadic and then systematic observations of the atmosphere above the Earth's surface began. This advancement spurred the development of a better scientific knowledge of meteorology, and the transfer of that knowledge to operations permitted better service to the Nation. Not until the second half of this century could reliable 2- to 3-day forecasts be generated routinely, and only within the last decade has that reliability been extended to 4 to 5 days.

Early development of upper-air observing systems provided the meteorologist with periodic snapshots of atmospheric activity by balloon-borne instruments. The introduction of weather radar in the late 1950's gave meteorologists their first capability to monitor the local weather patterns continuously, by observing the radar reflection from water droplets in an area surrounding the observation site. Installation of the radars that comprise the bulk of the present national radar network began in earnest in 1960. These original radars covered much of the U.S. South Atlantic and Gulf coasts, and a substantial portion of the Midwest. Radar installation continued through the 1960's, and by the early 1970's much of the eastern two-thirds of the country was under weather radar surveillance. Science capitalized upon technological innovation and explained the connections between water droplet patterns and rainfall and storm intensities, consequently providing an improvement in services by permitting, for the first time, reasonably reliable warnings of threatening severe storms.

Although the methodology for making numerical forecasts has existed since World War I, the introduction of the computer in the late 1950's provided meteorologists with the means for implementing those techniques. For the first time, the computational power existed to solve fundamental equations of fluid motion. The science of numerical weather prediction was born, permitting the study and forecast of atmospheric motion regionally and globally.

A basic concern of the precomputer age became painfully obvious in the age of numerical prediction: vast sections of the world, including the oceans, had few observations. The problems presented by the sparsity of data in these areas became more apparent when meteorologists attempted to extend the range of the forecast beyond 1 or 2 days. An effort to reduce the data sparsity problem has involved a system of Earth-orbiting satellites.

The first weather satellite was launched April 1, 1960. This launch introduced a new era for the environmental sciences. For the first time, more was available than just a collection of observations made at separate points on the ground by individuals, or simple representations of water droplets as shown by individual radars. Instead, from a vantage point in space, satellites provided a comprehensive aerial view of the Earth. As a result, satellites have contributed to the rapid development of environmental science and to the improvement of routine services.

II. CURRENT OBSERVING SYSTEM

The preceding section described the technological breakthroughs that moved the U.S. weather service from a handful of dedicated observers and recorders of the weather to a global system that can produce reliable predictions of the weather a few days into the future.

A. OBSERVING SYSTEM

The observing system currently in place is a composite one. It is composed of land–, ocean–, and space–based systems that measure a wide variety of environmental parameters. The system has evolved over more than 100 years, and changes have, until recently, occurred quite slowly. Each of the observing systems attempts to fill a niche for measurements needed to define the state of the atmosphere. The density of conventional surface and upper–air soundings in some portions of the globe, such as North America or Western Europe, far exceeds the density of similar information over oceanic and less developed regions. The current density of observations over North America has permitted improvements to forecasts of smaller scale events than has been possible in less developed regions. In effect, the quality of forecasts and services is directly correlated to the information available on atmospheric conditions, regardless of what scale of motion is examined. Put succinctly -- good forecasts require a plentiful supply of accurate data. Nowhere, however, has there been achieved a density and frequency of observations sufficient to meet the Nation's needs for forecasts and services.

Over areas of North America, the composite system includes approximately 80 upper–air sites, more than 1,000 manual surface observing stations, a few automated surface observing systems (with many more to come), pilot reports from aircraft (about 2,300 per day), a network of about 128 weather radars, over 10,000 cooperative observers, thousands of hydrologic data collection stations, Geostationary Operational Environmental Satellite (GOES) imagery and special soundings from the VISSR Atmospheric Sounder (VAS), and coastal marine observations. Currently deployed observing systems are continually pressed to provide information on synoptic and smaller scales of atmospheric motion; new ones are under development where the information needs are greatest. That information is used both manually and in numerical models for the production of guidance, forecasts, and a wide variety of services. The guidance, forecasts, and services are made available through an organizational structure that includes three National Centers, approximately 50 National Weather Service (NWS) Forecast Offices, and 250 Weather Service Offices.

Over large oceanic areas, the number and distribution of the different types of observing systems are drastically reduced; thus, other systems come to play more important roles. For instance, reports from ships, aircraft, a few buoys, and island stations are all the surface–based observations that are available. Much of the data from these observing systems are concentrated in limited geographical areas because of commercial transportation routes. The only other source of meteorological data over these vast ocean areas comes from the NOAA polar–orbiting and GOES satellites.

Image data from the geostationary satellites are used by NWS to provide a wide range of weather warnings and forecasts to the public, aviation, and marine communities. Offices with hurricane warning responsibility, including the National Hurricane Center (NHC), the Eastern and Central Pacific Hurricane Centers (EPHC, CPHC), and local forecast offices, use sequential GOES images to identify, track, and estimate the intensity of developing

tropical storms and hurricanes for an area stretching across the Atlantic Ocean to west of the Hawaiian Islands in the Pacific. Satellite image data are often the only source of real-time information across this vast oceanic area. Similarly, offices with international aviation and marine warning and forecast responsibility use the imagery to monitor the Northern Hemisphere from the mid-Atlantic Ocean (40 degrees W.) to the mid-Pacific Ocean (150 degrees E.), and issue high seas weather warnings over an area extending from 35 degrees W. to 160 degrees E. longitude. Satellite imagery is critical to the generation of warnings and forecasts of hazardous conditions such as gales, storms, tropical cyclones, high winds, and waves.

Quantitative weather parameters, such as cloud motion winds derived from GOES imagery, provide needed data to the National Meteorological Center (NMC) numerical models. These winds are routinely derived over data-sparse oceanic areas from 30 degrees W. to 180 degrees W. longitude, and 45 degrees N. to 45 degrees S. latitude. They are used in conjunction with the upper-air soundings as input to the computer models that predict the evolution and movement of major meteorological features such as jet streams and pressure systems. Global coverage of soundings and wind fields is required. Because numerical models are utilized for predictions beyond a few days, data from the tropics and Southern Hemisphere become increasingly important. Forecasts from the numerical models are the foundation for routine local weather forecasts over the United States. In addition, upper-air forecasts derived from these same numerical models are used by domestic and international air carriers for fuel-efficient flight planning over transoceanic routes.

The global temperature sounding data from polar-orbiting weather satellites, first available in the late 1960's and used operationally since the mid-1970's, have had a positive effect on numerical modeling activities. Studies conducted by the National Aeronautics and Space Administration (NASA) and NOAA on the quality of numerical weather analyses and forecasts produced with and without satellite data indicate a positive contribution from satellite data for forecasts over the North Pacific Ocean, North America, and Europe. The average reduction of error in 60 percent of the 5-day forecasts is near 10 percent. Studies conducted with wind and temperature data derived from both polar and geostationary satellites indicate improved upper-air analyses and forecasts. Forecast guidance issued to field forecast offices from NMC, containing data derived from satellites, has measurably improved over the past 15 years. Forecasts produced from this guidance have improved to the point that the forecasts of temperature and precipitation that are valid for 18-30 hours are as accurate today as forecasts valid for 6-18 hours were a decade ago.

The Polar-orbiting Operational Environmental Satellites (POES) are used not only as space platforms for sounding the atmosphere over oceanic areas but also as systems of critical importance that provide the following:

- The only means of observing the cloud and weather patterns for the State of Alaska
- A globally consistent set of sea surface temperatures (a critical climate measurement)
- A global radiation budget for climate system monitoring
- Ice monitoring in the polar regions and Great Lakes (offshore oil and gas exploration, maritime transportation)
- Vegetation Index maps for monitoring the planting, growth, harvesting, and health of crops worldwide

- A data collection and platform location system for monitoring ocean currents, tracking icebergs, and conducting research related to wildlife migrations and upper-air global wind patterns

- A collection of critical oceanic and hydrologic data from remote areas, providing needed platform location data (critical data from data-sparse ocean regions, flood warnings)

- A search and rescue transponder to locate downed aircraft and ships in distress (more than 350 lives have been saved to date)

The present U.S. Weather Watch system is depicted in Figure 1.

B. USE OF OBSERVATIONAL DATA

Data without the means to use them in a timely and effective manner are less useful to forecasters and other users. Observational data are used by NMC to prepare centrally produced guidance and by the local forecaster directly. The guidance products produced at NMC require the acquisition of a sufficient number of observations and global three-dimensional coverage. Both statistical and subjective guidance products are prepared from the dynamical atmospheric models. The local forecasters have many observations, including satellite images, to use in developing local warnings and forecasts. Thus, the many thousands of observations are used quantitatively and subjectively by the central guidance forecast functions and by the local/regional forecaster.

NOAA is involved in a number of programs, although limited in scope and deployment, that focus on the development and operational use of interactive processing and display systems. An enhancement to NWS's operational Automation of Field Operations and Services (AFOS) will provide the NWS Forecast Offices with the ability to better utilize satellite imagery and products. This system, called the Satellite Weather Information System (SWIS), will be implemented within the next 2 years.

Since 1980, the National Severe Storms Forecast Center (NSSFC) in Kansas City, Missouri, has provided the ability to integrate the real-time geostationary satellite data interactively with the other meteorological sources for the preparation of severe weather watches. The Centralized Storm Information System (CSIS), implemented by NOAA and NASA and based on the University of Wisconsin Man-computer Interactive Data Access System (McIDAS), provides that capability.

Verification studies conducted at the NSSFC for medium-range severe thunderstorm and tornado watches, and other severe weather events (6 to 12 hours), indicate a dramatic increase in the percentage of tornado watches verified from 1981 (43 percent) to 1984 (59 percent). Managers at the NSSFC attribute the improvement to the use of GOES satellite data on CSIS. This computer system combines digital satellite data with radar data, conventional data, and NMC forecast guidance products to provide meteorologists with interactive analytical capabilities in real time. This combination is critical for mesoscale severe storm forecasting.

Studies conducted at the NOAA Program for Regional Observing and Forecasting Services (PROFS) in Boulder, Colorado, indicate a similar improvement relative to the experimental issuance of short-range warnings (minutes to a few hours) of severe weather and attendant flash floods. These warnings are valid for areas smaller than one county.

Primary Observing Systems

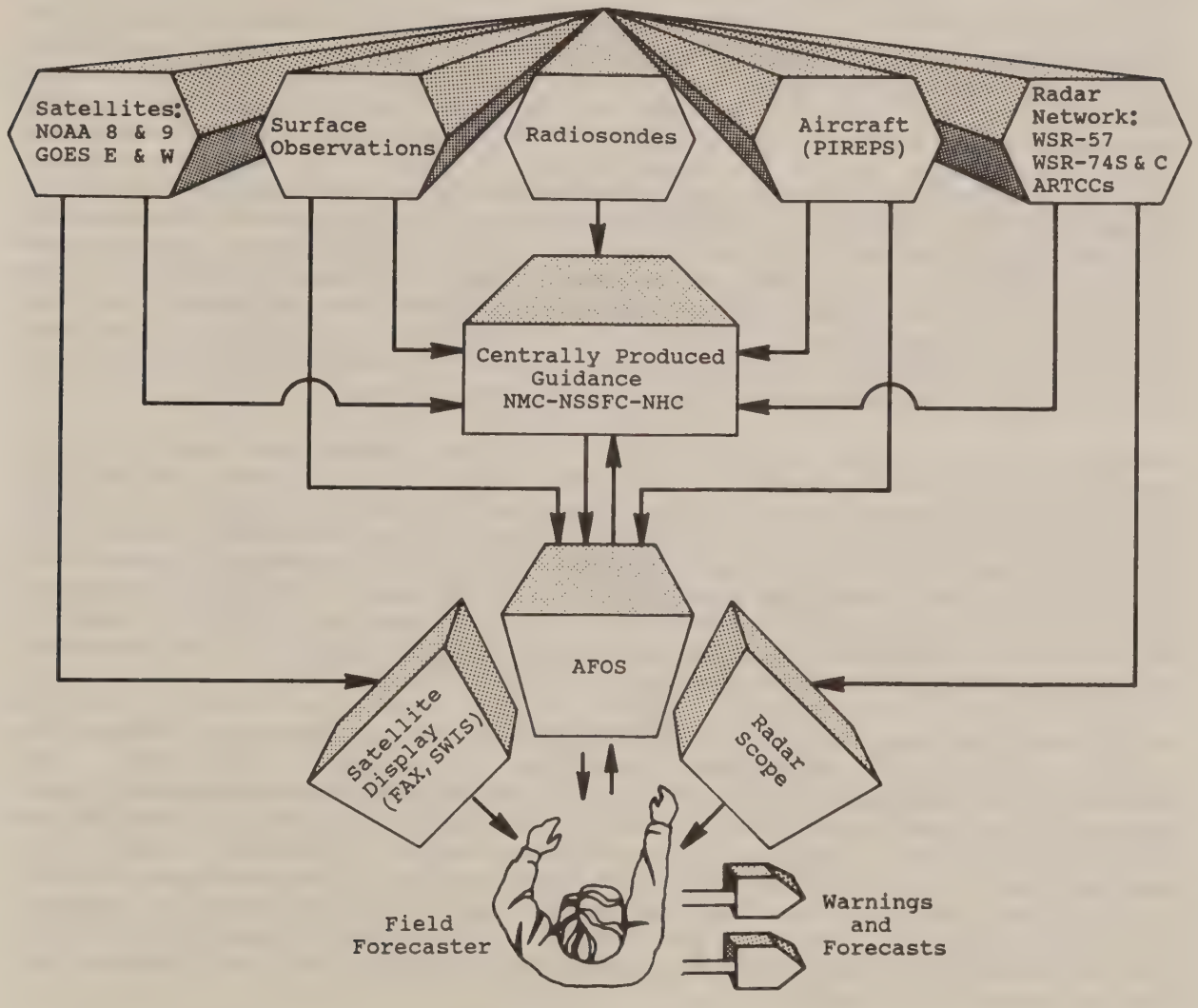

FIGURE 1

THE PRESENT U.S.

"WEATHER WATCH SYSTEM"

C. CURRENT PROBLEMS

Regardless of how effective the present observing and interactive processing and display systems are, it is not feasible simply to continue them as currently deployed. Much of the present equipment is obsolete and has limited capacity, resulting in increased failure rates and a high cost of operation and maintenance, and must be replaced.

In moving forward to replace this system, the opportunity is available to capitalize on recent technological advances that promise to improve the ability to observe and forecast the weather. Experience has shown that as each new technology was introduced (e.g., radar, satellites, computers), a better scientific understanding was translated into enhanced operations and improved forecasts and services. The surface weather and upper-air systems do not stand alone, nor do the radars or the satellites. The hydrometeorological observations provided are complementary, and together offer a better understanding of the current state of the atmosphere. The data provide the basis for the present meteorological and hydrological forecast system in this country. The hydrometeorologist must integrate information from all these sources to prepare forecasts and warnings. The process for collecting standard surface observations (such as temperature, pressure, humidity, and cloud ceiling) is labor intensive and not as extensive as it needs to be to forecast the weather. This system will be replaced with an Automated Surface Observing System (ASOS) capable of providing ground measurements in a more cost-effective manner.

Similarly, it is not feasible to continue with the current ground-based radar technology beyond the late 1980's, because the WSR-57 network radars are 1950's vacuum tube technology, which has already exceeded its productive physical and technological lifetime. To keep the network going until the Next Generation Weather Radars (NEXRAD) are available, newer WSR-74S radars have replaced seven of the most troublesome WSR-57s. Also, parts have been stockpiled, especially critical components that are in short supply or have a long lead time for procurement. These actions will keep the network functional for a few more years. However, because of the age and condition of the WSR-57s, it is neither feasible nor cost effective to keep them operational indefinitely.

The current radars not only are old but also do not have the new technology advancements, which include Doppler measurement capabilities and information processing. These capabilities will provide wind measurements on small spatial and temporal scales, digital reflectivity data and derived rainfall rates, and modern data processing to organize and display the information. The digital radar reflectivities and Doppler data available from this new generation of radar will provide increased probability of severe storm detection, increased lead time for flash flood events, decreased false alarm rate, and improved precision in defining the exact area and timing of a severe weather event. NEXRAD data also will provide many other important applications to improve short-range forecasts and aviation meteorological services.

The current geostationary and polar-orbiting meteorological satellites also require changes in the information they provide. Experience with VAS data has proceeded to the point where VAS data and products must be supplied without interference with other geostationary missions. Also, higher resolution information is required in the infrared, and image products need to be navigated more accurately to enable them to be combined with high-resolution radar information. Plans are under way to address these shortfalls. The polar orbiter soundings, now crucial to the production of global numerical forecasts, also must be improved by providing better accuracy and vertical resolution.

The primary operational satellite data distribution system currently in use is a network in which analog facsimile data are distributed via voice-grade telephone circuits. When the network began in the early 1970's, the GOES satellite system confronted system planners with a tremendous increase in the volume of data to be distributed. Complicating the problem were the limited availability of wide band communications facilities, excessive costs of the data storage systems and, at that time, an uncertain market for the GOES data, which hindered any justification of a large-scale development effort. These concerns resulted in the design of the current GOES-Tap system, which is based on acquiring and processing the data centrally, partitioning the data into segments compatible with voice-grade communication line capacity, encoding the data into an analog facsimile format, and distributing the data over voice-grade circuits to end users via regional hubs called Satellite Field Services Stations (SFSSs).

As great as the revolution in technology is the change in the requirements and expectations of the satellite data users. Satellite data are no longer an interesting experiment; rather, they are now an essential, and in many cases the principal, observing tool for environmental analyses and prediction. Although there will always be a class of users content with viewing a pictorial presentation of clouds, the more experienced and sophisticated user seeks higher resolution quantitative measurements, more timely delivery, multiple data types, and an effective means of comparing and evaluating products from many different sources. What is needed is a national data distribution system capable of effectively providing timely delivery of this greatly increased volume of information.

The AFOS system, which now serves as the "nerve system" of NWS field operations, is 6 years old. This system carries the weather observations, analyses, and forecasts to all NWS offices. The economic replacement strategy defined by private industry presently places a useful and economic lifetime of approximately 7 years on electronic equipment of this nature. Some of the AFOS subsystems are being modified to make it possible to continue operation of the system in the late 1980's; however, the entire system will require replacement by 1990. Plans are under way for developing an Advanced Weather Interactive Processing System for the 1990's (AWIPS-90). A new data distribution system must be developed to deliver the full benefits of the improved observing systems such as NEXRAD and the next generation of geostationary satellites (GOES-Next) to field operations.

The effort to modernize these systems is best understood when divided into the near term (the 1980's) and the long term (the 1990's).

III. NEAR-TERM OUTLOOK FOR THE WEATHER WATCH

The current system, which is expected to change significantly through the 1980's, will be characterized by:

- Operational use of VAS data
- Use of exchanged satellite data (NOAA/DOD shared processing)
- Deployment of Automated Surface Observing Systems (ASOS)
- Deployment of a national network of Doppler radars (NEXRAD)
- Automated aircraft observations from a number of ocean routes
- Limited deployment of the Automated Shipboard Aerological Programme (ASAP) on merchant ships
- Increase in the deployment of buoys (both moored and drifting)
- Decline in the number of ocean weather ships
- Continued automation and improvements in conventional upper-air soundings
- Deployment of an initial small network of surface-based wind profilers
- Enhancement of Automation of Field Operations and Services (AFOS) by the Satellite Weather Information System (SWIS)
- Numerical weather prediction enhancements

A. SATELLITE IMPLEMENTATION

NOAA and NASA have been engaged in research activities directed at benefiting from the GOES VAS instrument currently installed on U.S. geostationary satellites. Over a number of years, NOAA has gradually introduced VAS data and products into the operational environments of NWS Forecast Offices and National Centers. As part of the implementation, VAS Data Utilization Centers (VDUC) are to be deployed at all three National Centers, providing early and effective use of VAS data. Currently, only the NSSFC has a stand-alone interactive system (CSIS) that enhances the use of VAS and other information. Plans are under way to procure an updated system for the NSSFC to further enhance its use of VAS data and products. This system and the NHC VDUC system are scheduled for implementation in the late 1980's.

The Shared Processing System (a high-speed, satellite-based communication network connecting the major NOAA, Air Force, and Navy satellite data processing centers) will be on line in the late 1980's. This system will permit the interchange, in near-real time, of data obtained by the current NOAA and Defense Meteorological Satellite Program (DMSP) satellite systems.

B. AUTOMATED SURFACE OBSERVING SYSTEM

The near-term improvements in the ground-based weather watch network will include the automation of standard weather observations such as temperature, pressure, and winds. Much of the equipment for making surface measurements dates back to the pre-Korean war era. The NWS, the Federal Aviation Administration (FAA), and the Department of Defense (DOD) currently are working together to solve the problems associated with automating the ground-based surface observing system. A demonstration project at seven locations in Kansas is validating the design and operational utility of the ASOS. All current procurements of ground-based sensors are designed to be compatible with this automated observing system.

C. DOPPLER RADAR (NEXRAD)

NEXRAD will be the first operational Doppler weather radar system. The Doppler capability allows direct measurement of wind velocity and velocity spectrum width, providing important insight into internal storm structure, motion, and severity. Equally as important, the NEXRAD system will provide digital reflectivity and powerful computer processing of precipitation intensities, storm potentials, and other hydrometeorological fields. The new data derived from a network of NEXRAD radars with 10 cm band width and velocity detection will sharply decrease the frequency of false alarms for a variety of severe weather events.

For a large class of tornadoes, including those most dangerous to life and property, warning time is now essentially nonexistent. Warning lead times of 20 to 30 minutes are expected to be provided, giving vital time for persons in areas threatened by a tornado to take shelter. This will result in substantial savings of life and reduction of injuries. Modest reductions in property damage also will be realized where the warning lead time provides an opportunity to protect or relocate high-value transportable property. Similar savings will be realized from improved precipitation estimations (and attendant better flash flood warnings), hail and damaging winds detection, and winter storms forecasting. Doppler radar also will provide important data to improve the accuracy of national (large-scale) weather forecasts.

The benefits of NEXRAD are not limited to the severe weather events. Improvements in the accuracy of estimating areal precipitation will benefit the entire hydrologic effort. Similarly, savings in lives and resources are expected in the aviation community through the reduction of fatal weather-related accidents and the rerouting of aircraft as a result of NEXRAD-observed severe weather.

D. AIRCRAFT TO SATELLITE DATA RELAY

Wide-bodied jet aircraft of many nations are expected to carry Aircraft to Satellite Data Relay (ASDAR) equipment during the late 1980's. This system will provide wind and temperature information at up to 7-minute intervals from takeoff to landing on a number of Atlantic and Pacific ocean routes. Data will be relayed via the geostationary satellite international data collection system. ASDAR will provide more timely and frequent aircraft data than currently provided by manually produced pilot reports.

E. AUTOMATED SHIPBOARD AEROLOGICAL PROGRAMME

ASAP, now under development by Canada and the United States, and a similar system developed by France are expected to be deployed by 1988 on merchant ships on North Atlantic and Pacific routes. ASAPs will provide largely automated radiosonde soundings of the atmosphere twice daily along major ship routes. ASAPs will generate additional key ocean radiosonde measurements by enabling the merchant ships to produce soundings with less crew involvement and training.

F. BUOYS

Drifting buoys are expected to be deployed in increasing numbers in the North Atlantic and Pacific in the late 1980's. Sea surface, air temperature, and wind are the primary elements measured. Other more complex buoys measure a number of oceanographic parameters. Some fixed buoys also will be deployed at critical coastal locations where enhanced meteorological information is required to provide marine services.

G. OCEAN WEATHER SHIPS

Ocean Weather Ships (OWS) will continue to be phased out because of their high cost of operation and the availability of alternative observations. OWSs on the Atlantic Ocean are expected to decline from 4 to 2 by 1988; they may be phased out completely by the end of the decade.

H. AUTOMATED RADIO THEODOLITE

The basic upper-air observing equipment is Korean war vintage. NWS is currently conducting a modification program called Automated Radio Theodolite (ART), which will upgrade and automate the existing upper-air tracking systems by replacing outdated subassemblies with state-of-the-art solid state modules. Other modules will be added to allow automatic operation. To fully automate the system, it will be necessary to develop computer software that will recognize the meteorological data transmitted by a time-commutated radiosonde.

The first installations of ART began in the spring of 1983; implementation is expected to be complete by late 1986. This approach was taken with the hope that the ground-based and satellite-based remote sounders could eventually replace radiosonde soundings as the primary method of determining the upper-air temperature, moisture, and wind structure. However, this replacement is not yet possible because of the accuracies and vertical resolution of the satellite soundings. Hence, provisions for retaining the upper-air system must be accommodated.

I. WIND PROFILER

Techniques for remote sensing of the atmosphere from ground-based instruments using acoustic, radio, and optical methods are currently under development. These remote-sensing techniques have advantages over those of instruments now in use by providing:

- Simultaneous measurements of parameters important to weather at many points throughout a large volume

- Continuous rather than intermittent data

- Highly automated operations

The NOAA Wave Propagation Laboratory and NWS are proceeding to procure and deploy a prototype network of 30 wind profilers across parts of Texas, Colorado, Oklahoma, Kansas, and Nebraska by the end of 1988. These profilers will be integrated into an operating system to provide a near-continuous, four-dimensional (space and time) description of winds above a mesoscale region. These data sets will be used and evaluated with respect to mesoscale forecasting, wind prediction for aircraft routes, and NMC modeling impacts, as well as desirable and undesirable system features. The evaluation is intended to result in the definition of operational requirements for a nationwide network decision. The combination of satellite and profiler information theoretically should provide improved soundings.

J. ENHANCEMENTS TO AFOS

The field offices of NWS do not have the advantages of the CSIS or PROFS system capabilities. The mid-1970's saw the introduction of automated work stations into the field offices with the AFOS system. However, AFOS currently does not permit the integration of radar and satellite data, nor does it have the effective interactive computational capability that has been so effectively demonstrated by CSIS and PROFS. Detailed radar data are still available on separate displays, and satellite data are available to the field offices only in hard copy facsimile photographs. Eight field offices have special responsibilities for interpreting the satellite data and preparing textual information for use by the rest of NWS in the forecast and warning functions. By 1987, NWS will have installed the Satellite Weather Information System in all Weather Service Forecast Offices (WSFOs). SWIS will permit animation of the satellite images and overlaying of other meteorological data to enable the forecaster to perform a mental integration of this information.

SWIS will support the acquisition and display of satellite imagery 15 minutes sooner than currently available. Animation, and the combination of satellite imagery and products with AFOS graphics, will provide an additional dimension that will increase the understanding of dynamic weather situations. This will improve performance in the warning and forecast programs at the WSFO level. No integration of detailed radar data is planned for AFOS; that capability is expected in the 1990's.

K. ENHANCEMENTS TO NUMERICAL WEATHER PREDICTION

During the 1980's, the NMC numerical models will incorporate improved physics and increased spatial resolution. Work also will begin on the development and testing of mesoscale models. The computer systems supporting these activities include a CDC Cyber 205, two NAS 9050s, one NAS 9070, and three IBM 4341s. The IBM 4341s are used for communications, to receive and relay data, and to transmit outgoing products. The speed of the Cyber 205 is highly dependent on the programs being run; for dynamical models, it is about 120 million results per second. The three NAS machines, taken all together, total about 35 million instructions per second (MIPS). These systems will experience some modest enhancements during the late 1980's.

IV. THE WEATHER WATCH OF THE FUTURE

The observing system of the 1980's is expected to change significantly in the 1990's, making available large quantities of high-resolution data from both space-based and ground-based sources. The ability to use that data effectively will require the development of powerful interactive processing and display systems. The following will likely characterize observations and their use in the 1990's:

- Availability of the new generation of geostationary satellites (GOES-Next)
- Significant improvements to polar-orbiting satellite sensors [Advanced Microwave Sounding Unit (AMSU) and Ocean Color Instrument (OCI)]
- Deployment of a national network of wind profilers
- Deployment of new ocean-sensing satellites such as the Navy Remote Ocean Sensing System (N-ROSS) and the European Space Agency's Remote-Sensing Satellite (ERS-1)
- Improvements in data communications
- Implementation of a new powerful interactive processing and display system (AWIPS-90)
- Development of new numerical models

A. GEOSTATIONARY SATELLITES

Research meteorologists at NASA and field forecasters at the NWS Satellite Field Service Stations have long been frustrated by the limits in the spatial and thermal resolution inherent in today's GOES VAS sensors. Both groups also have seen the potential in increased temporal frequency of GOES imagery. It is widely believed at NASA and NOAA that significant forecast improvements can occur by improving the spatial resolution of the infrared (IR) imagery channels from 8 km to 4 km, increasing the number of imagery channels from three to five, improving the data acquisition rate from 15- to 30-minute cycles to 5- to 15-minute cycles, increasing the thermal sensitivity to less than 1.0 °C for all IR channels, improving navigation of the imagery, and providing simultaneous imagery and soundings. These capabilities will be available in GOES-Next and are planned for 1990.

B. POLAR-ORBITING SATELLITES

Meteorological satellite technology, which is now 25 years old, has become a major part of the weather support system. The requirements for data and products levied upon the meteorological satellites in many cases still have not been fully met. For example, NWS has a requirement for high spatial resolution vertical soundings with vertical resolution and accuracies equivalent to the upper-air balloon system in clear and cloudy environments. These requirements have not been and cannot be met with today's satellite instruments. The next polar-orbiting spacecraft (NOAA K, L, and M) will contain the AMSU. The AMSU will move us closer to the operational need, because microwave sensors will permit soundings in cloudy areas with improved thermal accuracies and vertical and spatial resolution. The AMSU will provide the following:

- Higher horizontal resolution for temperature and moisture soundings (more compatible with the grid resolution of the forecast models).

- Better vertical resolution (comparable to clear soundings today) in the lower atmosphere, below clouds. (Forecast models require detailed information in the lower atmosphere, especially in the vicinity of storms.)

- Better definition of precipitation beneath clouds, because of higher resolution than current sounders. (Energy transfer to the atmosphere is from the latent heat of condensation.)

- Significantly improved water vapor measurements (in relation to energy transfer).

- Coverage of stratosphere temperature profiles to 30 km (climate diagnostics).

An Ocean Color Instrument, not yet approved, also is being considered for the NOAA K, L, and M series. This instrument would be used primarily to monitor chlorophyll concentration, which is a measure of the abundance of phytoplankton. This information would be used by the NWS, the National Ocean Service (NOS), and the National Marine Fisheries Service (NMFS) to aid in the detection of water masses, ocean currents, and eddies.

C. PROFILER

The prototype network of 30 wind profilers will help NOAA decide whether or not to implement a large national network of wind profilers during the 1990's. Profilers that sense temperature and moisture of the lower atmosphere, as well as wind, will continue to undergo research and development. If certain technical and cost problems are overcome, their data, when used in conjunction with satellite sounding information, may provide further enhanced data for use by forecasters and in the mesoscale models expected in the 1990's.

D. OCEAN SENSING PROGRAMS

The need for timely and accurate measurements of the marine environment has increased dramatically during the past decade. Analyses and predictions of oceanic and coastal conditions are essential for supporting rapidly increasing maritime activities. The availability of satellite data is of primary importance for improvements in derived ocean surface information from both polar-orbiting and geostationary satellites.

Programs expected to provide ocean measurements in the early 1990's will include data from the Navy Remote Ocean Sensing System (N-ROSS) and the European Space Agency (ESA) Remote-Sensing Satellite (ERS-1). They will provide wind and other oceanic parameters. Future oceanic satellites equipped with various sensors will provide a myriad of parameters needed by NWS. The sensors on these satellites will be both active and passive.

- Scatterometers will provide global sea surface wind fields and wave height information, which will enable scientists to study waves, wind-driven ocean circulation, and the interaction between the oceans and atmosphere.

- Altimeters will measure sea surface topography. The data will provide information on ocean currents and waves. The altimeters also will be used for determining ice sheet heights and ice boundaries.

- Radiometers will provide all-weather global sea surface temperatures, ice age, rainfall rates, wind speed, and atmospheric water vapor content.

- Synthetic Aperture Radar (SAR) will resolve ice boundaries to the order of tens of meters. The high-resolution ice data will determine individual ice floes and their motions, which will impact navigation and mineral exploration.

The data derived from these instruments should help to improve the efficiency, safety, and effectiveness of marine transportation, offshore exploration, construction, and scientific knowledge of ocean surface dynamics.

E. DATA COMMUNICATIONS

Today's communications capabilities are quite different from those that existed in the early 1970's. The common carrier communication networks have expanded greatly, and an oversupply of communication satellite transponders has been predicted over the next few years. Plans have been announced for installation of wide band fiber optics links connecting most of the major cities in the United States. New technology has made available to satellite data users affordable high-performance computers, low-cost mass memories, inexpensive satellite terminals, small image processors, and effective digital satellite data applications techniques.

Major improvements in data communications are required to meet the needs of the field forecaster in the 1990's. One configuration under consideration that would satisfy the data communication needs is the adaptation of a commercial satellite distribution system presently being used to provide audio to radio stations throughout the United States. This system would offer the NOAA data user a complete ground terminal, antenna through interface, with both analog and digital product mix, at low cost as compared with a single "stretched VISSR" terminal. Approximately 2,000 units are currently in operation for radio network program distribution. The system is digital, incorporating forward error correction and a net throughput of 7.68 megabits per second. While all products must be uplinked from a central location, presumably in the Washington, D.C., area, they could originate anywhere.

A phased implementation would include the present sectorized analog images followed by the new GOES digital data streams. As image terminals are implemented, the analog images would eventually be phased out except for minimal backup. New digital products would be inserted as they became available. When fully implemented, the operator could select GOES-East or GOES-West data, other satellite data, and derived products in analog or digital format.

F. INTERACTIVE PROCESSING AND DISPLAY SYSTEM

The 1990's will be a period when data from systems such as satellites, radars, and profilers, as well as a host of conventional observing systems and centrally generated guidance products, will be available to the field forecaster. Without powerful interactive processing and display systems to organize and provide manipulation of that information, the forecaster will be overwhelmed and the full benefit of the information will not be realized. NWS is currently planning to develop and deploy the AWIPS-90. The CSIS and PROFS experiences in such technology are providing information and a means by which requirements can be examined and validated.

The AWIPS-90 work station will provide the best available information on the state of the atmosphere for the field meteorologist's region of responsibility. Using this information and the capability of AWIPS-90 to manipulate and display that information, the forecaster will be able to keep aware of the weather as it develops, and provide faster and more accurate alerts and warnings to the public. AWIPS-90 also will offer powerful support to diagnostic and predictive techniques directed at improved forecasting of small atmospheric scales of motion.

The U.S. Weather Watch system of the 1990's is depicted in Figure 2.

G. NEW NUMERICAL MODELS

Numerical weather prediction models will react to the advances in science and technology during the 1990's. Resolution of the models will be greater to match more dense and more accurate observations, particularly from satellites but also from ground-based instruments with new technologies such as microwave and lidar sounders. Advances in computer technology will permit the optimum utilization of this expanded data set by the higher resolution models. Contemporary advances in science will be required for the high-resolution models to yield improved predictions. Prediction accuracy depends on how well the interchange of heat, momentum, and moisture at the upper and lower boundaries is handled. This, in turn, requires the improved observations of sea surface temperature that are projected from new satellite-borne instruments.

Operational implementation of mesoscale models by NWS in the early 1990's will include two levels of complexity. The most complex models will be operated at NMC. However, more simplistic mesoscale models may be implemented in field offices with the deployment of AWIPS-90. The end of the decade may see the use of dynamic/stochastic models that address the variances of forecast elements.

Primary Observing Systems

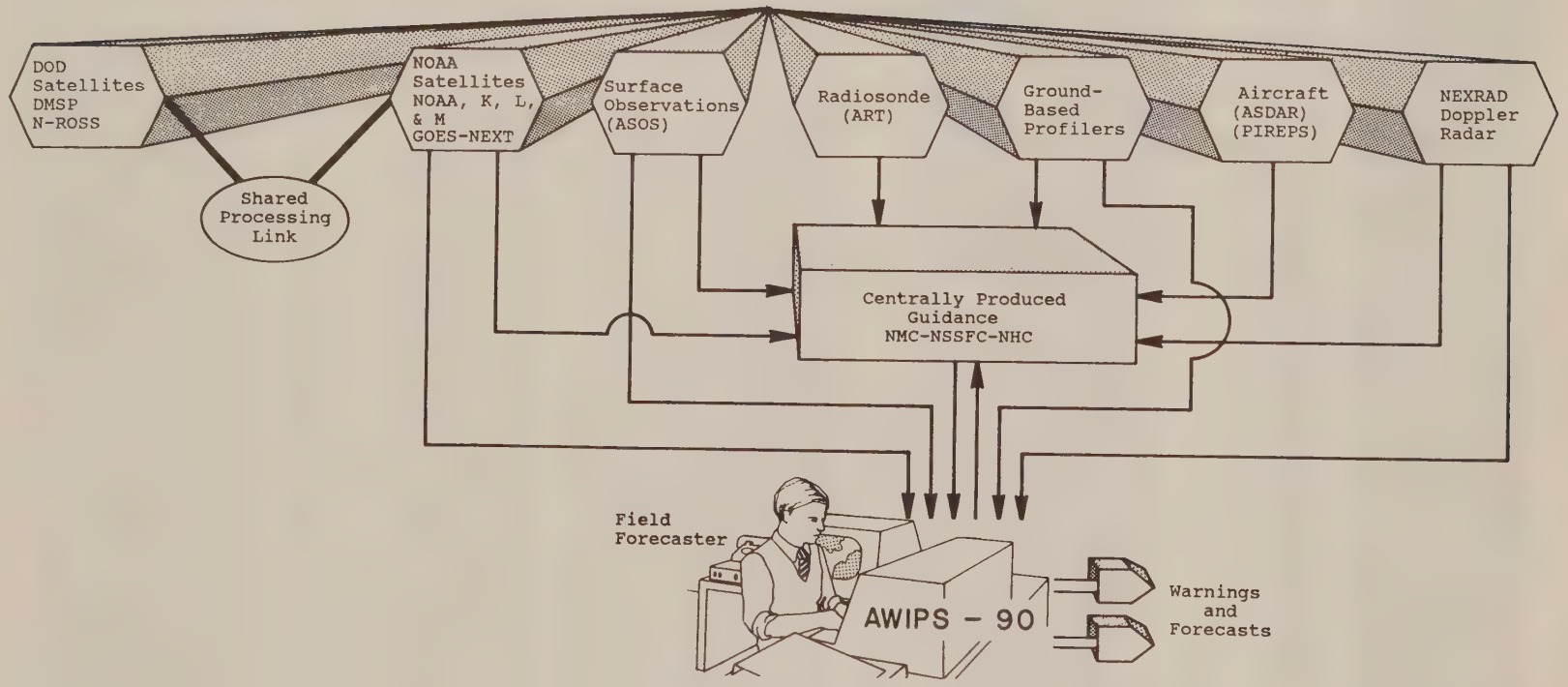

FIGURE 2

THE FUTURE U.S.

"WEATHER WATCH SYSTEM"

V. CONCLUSIONS

In reviewing the present observing system and those developmental efforts expected to result in the availability of much improved observational information for forecast and warnings through the year 2000, several important conclusions become clear. They are:

- For the foreseeable future, no single system will fill the entire observing need; however, remote sensing from surface– and space–based instruments will play a larger and more crucial role.

- To gain a significantly increased measure of utility from the observing systems that provide high spatial and temporal resolution data, it will be necessary to develop and deploy powerful interactive processing and display systems.

- Providing vast amounts of environmental information will require an advanced communications system that delivers information in a detailed and timely manner.

- Analysis and forecast models running on improved computer systems will be capable of handling the increased observational data and providing better and more detailed forecasts.

APPENDIX A

GLOSSARY OF ACRONYMS

AFOS	–	Automation of Field Operations and Services
AMSU	–	Advanced Microwave Sounding Unit
ART	–	Automated Radio Theodolite
ASAP	–	Automated Shipboard Aerological Programme
ASDAR	–	Aircraft to Satellite Data Relay
ASOS	–	Automated Surface Observing System
AWIPS–90	–	Advanced Weather Interactive Processing System for the 1990's
CPHC	–	Central Pacific Hurricane Center
CSIS	–	Centralized Storm Information System
DMSP	–	Defense Meteorological Satellite Program
DOD	–	Department of Defense
EPHC	–	Eastern Pacific Hurricane Center
ERS	–	ESA Remote–Sensing Satellite
ESA	–	European Space Agency
FAA	–	Federal Aviation Administration
GOES	–	Geostationary Operational Environmental Satellite
GOES–Next	–	Next Generation Geostationary Satellites
IR	–	Infrared
McIDAS	–	Man–computer Interactive Data Access System
MIPS	–	Million Instructions per Second
MSU	–	Microwave Sounding Unit
NASA	–	National Aeronautics and Space Administration
NESDIS	–	National Environmental, Satellite, Data, and Information Service

NEXRAD	–	Next Generation Weather Radar
NHC	–	National Hurricane Center
NMC	–	National Meteorological Center
NMFS	–	National Marine Fisheries Service
NOAA	–	National Oceanic and Atmospheric Administration
NOS	–	National Ocean Service
N-ROSS	–	Navy Remote Ocean Sensing System
NSSFC	–	National Severe Storms Forecast Center
NWS	–	National Weather Service
OCI	–	Ocean Color Instrument
OWS	–	Ocean Weather Ships
POES	–	Polar-orbiting Operational Environmental Satellite
PROFS	–	Program for Regional Observing and Forecasting Services
SAR	–	Synthetic Aperture Radar
SFSS	–	Satellite Field Services Stations
SWIS	–	Satellite Weather Information System
VAS	–	VISSR Atmospheric Sounder
VDUC	–	VAS Data Utilization Center
VISSR	–	Visible and Infrared Spin-Scan Radiometer
WSFO	–	Weather Service Forecast Office